PLANETARY SCIENCE

A NEAR Miss Seeking the Origin of Meteorites

The NEAR spacecraft got a close look at asteroid Eros through an array of remote-sensing instruments but failed to nail down the source of most meteorites

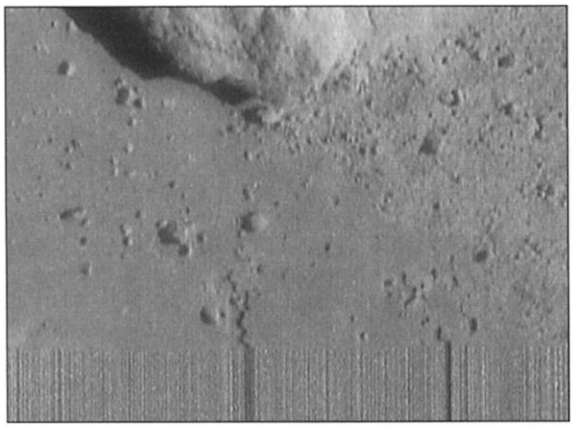
Planetary geology can be a frustrating endeavor. A career might be spent studying a planetary body from afar without ever laying hands on an actual rock. Asteroid specialists have it better—chips of asteroids fall to Earth as meteorites—but studying the objects in their natural environment can still be exasperating. Take the latest effort to match the most common meteorites with a particular type of asteroid.

For the past couple of decades, some planetary scientists suspected that so-called S-type asteroids are the source of the most common meteorites, the ordinary chondrites. Their spectroscopic "color" as seen from Earth matched pretty well. But it wasn't close enough to be convincing. So, in a test of the power of planetary science's bread-and-butter remote-sensing technology, NASA sent the NEAR Shoemaker spacecraft to orbit the asteroid Eros and resolve the matter. Now the verdict is in: The evidence still leaves room for reasonable doubt.

In one of six mission papers in the December issue of *Meteoritics & Planetary Science*, meteoriticist Timothy McCoy of the Smithsonian Institution's National Museum of Natural History and fellow team members pull all the remote-sensing data together and conclude that Eros most likely is an ordinary chondrite. "But that's not the only possibility," says McCoy. "Until we get a sample return, this may remain an open question." The uncertainty arises from the inherent limitations of remote sensing as well as design limitations of the first of NASA's "faster, cheaper, better" planetary missions.

The first link between meteorite and asteroid came through ground-based, telescopic analyses of visible and infrared radiation. To judge by the absorption at specific wavelengths, the S(IV) subclass of asteroids seemed to have the same mix of minerals as the ordinary chondrites, lumps of primordial material left over from the formation of the solar system. A subtle reddish tint to the asteroids, however, suggested to some planetary scientists that they might have differentiated, or melted and separated into rock and metal. That would mean S(IV) asteroids such as Eros couldn't be ordinary chondrites. Other planetary scientists suggested that Eros's redness is only skin deep—the result of space weathering, an alteration of the outermost few micrometers of rock presumably due to micrometeorite impacts or radiation damage.

To cut through the space weathering debate, NASA equipped NEAR Shoemaker with the full range of remote-sensing technologies (*Science*, 9 February 1996, p. 757). A multispectral imaging system and a near-infrared spectrograph would gauge the mineral composition of small areas—a boulder or an impact crater floor—that might expose unweathered chondritic rock. But the mission's ace in the hole was an x-ray–gamma ray spectrometer that could cut through any spectral cloaking of the asteroid and determine its elemental composition. Although space weathering might redden chondrites, researchers reasoned, it can do little to alter their distinctive elemental composition.



So close. Although NEAR Shoemaker got a detailed look at Eros, remote sensing proved no substitute for a sample.

After analyzing NEAR Shoemaker data from a year in orbit and 10 days after it landed on the surface in a death-defying descent, team members are sure about one thing: "It's definitely undifferentiated," says McCoy. Eros is so stunningly uniform across its surface that it seems highly unlikely that it ever separated completely into rock and metal (*Science*, 9 June 2000, p. 1714). "Eros is something like an ordinary chondrite," McCoy adds, "or a slightly modified ordinary chondrite," but it's still not clear whether that modification is superficial or deep-seated. Eros could, for example, be a primitive achondrite, made of the same stuff as chondrites but heated just enough to destroy the pebbly texture of chondrites.

There are no primitive achondrites in the world's collection of meteorites that would match NEAR Shoemaker's characterization of Eros, but then there are no ordinary chondrites that would match, either. X-ray spectrometry found a dearth of sulfur relative to chondrites, something conceivably attributable to space weathering. But the gamma ray spectrometer detected relatively less iron when it landed than found by x-ray spectrometry from orbit or in ordinary chondrites. And two different ways of inferring mineralogical composition from the visible-infrared data place Eros in two different subclasses of ordinary chondrites.

Some NEAR Shoemaker team members look on the bright side. "It didn't come out so crystal-clear as one might have expected," says asteroid specialist Clark Chapman of the Southwest Research Institute in Boulder, Colorado, "but it seems to converge on being an ordinary chondrite." Others are less sanguine. "I would say it's not a very strong conclusion," says Larry R. Nittler of the Carnegie Institution of Washington's Department of Terrestrial Magnetism, who headed up the analysis of the x-ray data. "It's frustrating we can't unambiguously say 'This is the answer.' "

Researchers offer many reasons why NEAR Shoemaker fell short of unambiguous success. "Some of the uncertainties are inherent" in remote sensing, notes McCoy. Knowing the distribution of particle sizes in the debris "soil" that covers asteroids is crucial in analyzing remote sensing, for example, but "we won't know that until we bring a sample back," he adds. Other uncertainties involve spacecraft design. Due to money and weight constraints imposed by NASA's "faster, cheaper, better" Discovery program, NEAR Shoemaker was the first spacecraft to carry a gamma ray spectrometer mounted within the body of the spacecraft rather than at the end of a long boom. A boom would have kept the spectrometer away from the gamma rays produced when cosmic rays hit the spacecraft. The resulting background noise was one reason no one has yet bothered to analyze any of the gamma ray data taken in orbit.

Although NEAR Shoemaker researchers hope to wring more understanding from their data, McCoy and colleagues look to a rover–sample return mission to sort out the nature of S(IV) asteroids. The Japanese MUSES-C mission, due for launch in late 2002, promises to return a sample from S(IV) asteroid 1998 SF36 in 2007. No rover mission is in sight.

–RICHARD A. KERR

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